THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Nuclear and Radiation Studies Board

500 Fifth Street, NW
Washington, DC 20001
Phone: 202 334-3066
Fax: 202 334-3077
www.nationalacademies.org

February 14, 2008

Mr. Mark Gilbertson
Deputy Assistant Secretary for Engineering and Technology
Office of Environmental Management
U.S. Department of Energy
Washington, DC 20585

Subject: Technical and Strategic Advice for the Department of Energy, Office of Environmental Management's Development of a Cleanup Technology Roadmap: Interim Report

Dear Mr. Gilbertson:

The fiscal year (FY) 2007 House Energy and Water Development Appropriations Report directed the Department of Energy (DOE) to prepare a technology roadmap that identifies technology gaps in the current DOE site cleanup program and a strategy, with funding proposals, to address them. At the request of DOE's Office of Environmental Management (EM), the National Research Council (NRC) empanelled a committee to assist DOE in developing the roadmap (Sidebar 1).[1] You requested the committee, as a part of its ongoing study, to provide an interim report to inform EM's deliberations on its FY 2009 plans for cleanup technology development. This interim report responds to your request.

Considering the limited time available to prepare this interim report at about the midpoint in its study, the committee chose to summarize its initial observations that bear on the importance of a strong EM-directed research and development (R&D) program to meet EM site cleanup challenges, and to underpin these observations with a few important examples of needs and opportunities for EM R&D. The committee's final report, to be issued in February 2009, will be developed in accordance with the full statement of task.

The committee began its study with a March 2007 workshop at which DOE site representatives, regulators, and citizens described cleanup challenges and technology needs (gaps) at DOE's four major cleanup sites: the Oak Ridge Reservation, Tennessee; the Idaho National Laboratory; the Hanford Reservation, Washington; and the Savannah River Site, South Carolina. Technology needs identified during the workshop as well as those identified by previous NRC committees are summarized in the workshop report (NRC, 2007). These needs generally fall into all five program areas in EM's draft roadmap listed in Sidebar 1. Some of the

[1] The committee's statement of task for this study is included as Attachment 1 and the committee roster is included as Attachment 2.

sites' higher-priority, longer-term needs are presented as examples in the second part of this interim report.

To date, the committee has visited three of the four above-named sites[2] to complete its assessment of technology gaps and priorities, and to understand the research capabilities and infrastructure at their national laboratories that are relevant to EM needs. In February, 2008 the committee is holding a three-day closed session for detailed discussions of this study. In spring 2008, the committee will hold an information-gathering meeting in Washington, D.C., with representatives of EM, other DOE offices and federal agencies, universities, and the private sector to better assess how EM might leverage its R&D with other programs. The committee may also request additional information from the DOE sites before it completes its final report.

The committee generally agrees with the five program areas for strategic R&D initiatives presented in EM's draft Cleanup Technology Roadmap. However, based on the information it has gathered, the committee observes that implementing the roadmap will require substantial and continuing federal support for medium- and long-term R&D for technologies focused on high-priority cleanup problems. As used in this report, short-, medium-, and long-term refer to time periods on the order of 1-5, 5-10, and >10 years, respectively.

Observations

(1) The complexity and enormity of EM's cleanup task require the results from a significant, ongoing R&D program so that EM can complete its cleanup mission safely, cost-effectively, and expeditiously.

The wide range of operations carried out by DOE (and its predecessor organizations) during the past 60+ years has resulted in hazardous and radioactive waste accumulation in tanks, soil, groundwater, and buildings. The sheer size of the cleanup in terms of numbers of facilities, land area, and contaminated subsurface and groundwater volume is enormous—amounting to an estimated life-cycle cost of over $235 billion.[3] Within this tremendous undertaking, there are thousands of individual tasks. Many of these tasks are complex and unique (for example,

---

[2]The committee visited the Savannah River Site and the Savannah River National Laboratory in early January 2008, when this interim report was in review.

[3] In March 8, 2007, testimony before the House Committee on Appropriations, Subcommittee on Energy and Water Development, Assistant Secretary for Environmental Management James Rispoli reported that the estimated life-cycle cost for the DOE cleanup program had increased to about $235 billion owing to the addition of new projects as well as regulatory and *technology development problems* [ital. added] with current projects. DOE's fiscal 2009 budget request, which was released while this interim report was being prepared for printing, puts the potential cost of removing or remediating radioactive waste and other contamination at the sites between $265 billion to $305 billion, see (http://www.cfo.doe.gov/budget/09budget/Content/Volumes/Volume5.pdf).

cleanout of high-level waste tanks, separation and processing of radioactive wastes, and cleanup of structures and groundwater plumes contaminated with radioactive and chemically hazardous materials). Within each specific task, the compositions of the wastes or the contaminants, or other factors (e.g., tank or building age and structure, site geology), often differ sufficiently to require the work to be customized to the situation.

Congress and DOE have provided substantial funding for EM's investments in scientific research and technology development since EM was created in 1989. However, this funding has varied substantially—rising from $184 million in FY 1990 to almost $410 million in FY 1995, followed by a decade-long slide to around $20 million per year recently (NRC, 2007).

Several previous NRC committees from which EM has sought advice have recognized the need for a strong science and technology base for site cleanup work. The 1997 report Building an Effective Environmental Management Science Program (EMSP) stated that "given the size, and scope and long-term nature of DOE's cleanup mission, the committee views the establishment of the EMSP as a prudent and urgent investment for the nation" (NRC, 1997, p. 12).

Sidebar 1

A Brief Description of the Draft EM Cleanup Technology Roadmap

The technology roadmapping process has been widely used as a planning tool in industry and government to match technology resources with desired product or process outputs. In the case of industry, these outputs are often products to meet certain commercialization needs. In *Vision 2020: The Lighting Technology Roadmap*, DOE used this technique in working with industry to align resources to meet new challenges in building lighting systems (DOE, 2007a).

The draft EM roadmap lists five program areas that are central to site cleanup:

1. Tank waste processing (including waste retrieval and tank closure),
2. Groundwater and soil remediation (including buried waste, flow path, and contaminant characterization),
3. Facility deactivation and decommissioning,
4. DOE spent nuclear fuel, and
5. Challenging materials (generally speaking, these are nuclear materials with no definite path to disposition).

Technical risks and uncertainties are listed in tabular format for each of these program areas. For example, within tank waste processing, the roadmap indicates that there are technical risks and uncertainties involving waste storage, waste retrieval, tank closure, waste pretreatment, and stabilization. Strategic initiatives to address each uncertainty are also listed.

A later committee concluded that the "uniqueness and complexity of DOE's EQ [environmental quality] problems demand that the EQ R&D portfolio have a strong, if not dominant, long-term component" (NRC, 2001, p. 4).

In directing EM to prepare the Cleanup Technology Roadmap, the fiscal year 2007 House Energy and Water Development Appropriations Report stated support for EM technology development work and cited another previous NRC report, as follows:

> "EM technology development program funding has declined over the years, while at the same time, many technological challenges continue to face the program. For example, the National Research Council's 2005 report on Improving the Characterization and Treatment of Radioactive Wastes recommends that 'an improved capability for environmental monitoring would strengthen EM's plans to leave waste and contaminated media at DOE sites,' and, 'Monitoring systems at EM closure sites have been estimated to be some 25 years behind the state-of-art.' The Committee directs the increase to address the technology short-falls identified by this report."[4]

After visiting three of EM's major cleanup sites and witnessing both the cleanup accomplishments and the enormity of the remaining cleanup tasks—as well as potential new tasks to be added from other DOE offices in the future—the committee judges that existing knowledge and technologies are inadequate for EM to meet all of its cleanup responsibilities in a safe, timely, and cost-effective way. Meeting current and future challenges will require the results of an ongoing R&D program.

(2) By identifying the highest cost and/or risk aspects of the site cleanup program, the EM roadmap can be an important tool for guiding DOE headquarters investments in longer-term R&D to support efficient and safe cleanup.

The committee recognizes that large sums of money are being spent to clean up DOE sites. This includes short-term applied R&D activities supported to varying degrees by cleanup contractors. The committee is concerned that the medium- and long-term research component of EM's program has largely disappeared.

Need for longer-term R&D: EM carries out its site cleanup mission by issuing contracts, usually through its site offices, for specified cleanup tasks. EM's cleanup work is thus being

[4] House Report 109-474 to accompany H.R. 5427, Energy and Water Development Appropriations Bill, 2007. The Appropriations Committee recommended a $10 million increase over DOE's initial budget request.

carried out by contractors at each site who have incentives to get the job done safely, on schedule, and within budget. As the contractors find it necessary, they may engage the national laboratories, universities, or other organizations to provide technical assistance. Accordingly, most funding for R&D tasks to support cleanup is presently provided by cleanup contractors for near-term technical support. However, given that cleanup contracts typically last from three to five years, contractors cannot be expected to provide sustained support for medium- and long-term R&D to meet EM's broader technology needs during the next approximately 30 years that the cleanup program is now expected to last.

Cleanup contractor-supported R&D is analogous to the industry practice of funding product-related R&D through business units. Experience from industry indicates that such units, driven by the profit/loss bottom line each quarter, make investments only for short-term results and incremental product improvements. Longer-term investments reduce the short-term financial performance of business units and are not generally funded by those units. However, it is the longer-term investments that are more likely to result in new product and process concepts. In industry, strategic R&D investments are usually made at the corporate level to ensure the future availability of innovative products.

Samsung, for example, describes its R&D funding in three tiers ranging from the business unit for product development, to division-level for core competencies, and corporate for future platform technologies.[5] By analogy, the role of DOE headquarters (corporate) would be to provide sufficient funding for integrated medium- to long-term R&D needs identified in collaboration with site cleanup contractors to support major improvements in the sites' cleanup operations.

Efficient approaches to addressing cleanup problems: Cleanup contractors typically bid on jobs according to a scope of work. However, EM cannot specify a scope of work or manage a contract effectively without first understanding the nature of the cleanup problem. For example, to scope a remediation task for the cleanup or containment of buried waste or a subsurface contaminant plume, a basic understanding of the problem would include the probable mechanisms and pathways by which contaminant migration could occur; how the contaminant migration could be stopped, curtailed, or intercepted; and the most effective remediation options that a contractor might implement. Such understanding of a cleanup problem is often based on the results of longer-term research, which as noted above, is seldom funded by the cleanup contractors.

The importance of research in understanding the nature of a cleanup problem was illustrated by Pacific Northwest National Laboratory (PNNL) in seven examples of apparently

[5] http://www.samsung.com/us/aboutsamsung/companyprofile/researchanddevelopment/CompanyProfile_RD_WorkforceOrganization.html.

anomalous contaminant migration at Hanford—the contamination was moving in unexpected amounts and/or directions. The reasons underlying the apparently anomalous behavior were resolved in each case by scientific study that led to improved approaches for remediation or containment of the contamination (Stewart, 2007).

Developing alternatives to baseline approaches requires a similar understanding of the cleanup problem. Other NRC committees have concluded that most cleanup requirements within EM's current scope can be met, but new technologies can provide more technical options that may make the work more efficient and less risky (e.g., safer and/or more likely to meet performance and cost objectives). One example, which was mentioned frequently to the committee, was the development of a solvent extraction method for removing cesium from tank waste. The new method resulted from basic research followed by an EMSP grant for applying this research to an EM problem. After exploring several alternative technologies for high-level waste salt processing, the Savannah River Site is implementing solvent extraction for cesium removal (NRC, 2000, 2006).

Whereas near-term technology needs are recognized and generally fulfilled by the cleanup contractors through outreach to appropriate resources, support for medium- and long-term research and technology development requires a plan (i.e., technology roadmap) that identifies high-priority R&D needs and defines a program to meet these needs.

(3) The national laboratories at each site have special capabilities and infrastructure[6] in science and technology that are needed to address EM's longer-term site cleanup needs. The EM roadmap can help establish a more direct coupling of the national laboratories' capabilities and infrastructure with EM's needs.

Dating back to the Manhattan Project, R&D at national laboratories led to the nation's first nuclear weapons and weapons material production. National laboratories played key roles in supporting large-scale production of materials for nuclear weapons throughout the Cold War. They also built on this expertise by expanding into areas such as nuclear energy and beneficial uses of radioisotopes.[7] Although the missions of the national laboratories have expanded to include most areas of cutting-edge science, expertise in basic radiochemistry, radiochemical separations, remote equipment operation and maintenance, nuclear instrumentation, and radiation monitoring remains a forte and is essential to addressing EM cleanup challenges. The laboratories also retain production-era infrastructure, including shielded hot cells where substantial amounts of highly radioactive materials and wastes can be handled. State-of-the-art

[6] The statement of task directs the committee to identify the national laboratories' capabilities and infrastructure relevant to EM needs. As working definitions, the committee considers "capabilities" to refer to the expertise of laboratory personnel and "infrastructure" to refer to facilities and equipment.

[7] Nuclear energy and isotopes programs would seem to offer opportunities for leveraging EM investments with other DOE offices, although they have not yet been discussed by the committee. A previous NRC (2003) report suggested possible beneficial uses for EM's excess nuclear materials.

computing facilities, which are part of today's national laboratory infrastructure, are also needed by EM, for example, to model cleanup options and estimate their effectiveness. New capabilities and infrastructure, such as those at the Oak Ridge Field Research Center, are clearly important for EM's work.

As production-era personnel retire from operations and the national laboratories, their knowledge of the former production facilities and waste disposal sites, which EM is tasked to clean up, will disappear unless there is sufficient EM support to attract new investigators with whom the experienced personnel can work to transfer their knowledge and expertise. Additionally, without EM support for university research, faculty will have little incentive to train the students who will provide future expertise for EM-related R&D.

As one would expect, the degree to which expertise and infrastructure are directed to cleanup problems is commensurate with the level of EM-headquarters and contractor support in the national laboratories' budgets. Relatively little EM work from either source is being supported at Oak Ridge National Laboratory (ORNL), which received about $15 million in total EM support in 2007 (Michaels, 2007). PNNL, which received about $91 million total from EM in 2007, provides substantial support for the Hanford cleanup (Walton, 2007). At PNNL most of the EM funds came through the cleanup contractors and were directed at site services (e.g., dosimetry), subject matter expertise, (e.g., tank waste chemistry or subsurface fate and transport), or near-term technology issues. Because of mission change, the Idaho National Laboratory (INL) has significantly shifted its research support of EM cleanup to short-term responses, although the laboratory has capabilities in many areas, especially in subsurface science that is necessary for the understanding of the fate of soil contaminants at each of the nuclear waste sites.

In 2006, DOE designated SRNL as the "corporate laboratory" for the DOE Office of Environmental Management.[8] In this capacity, SRNL has the responsibility to apply its unique expertise and technology capabilities to reduce technical uncertainties in meeting cleanup requirements across the DOE complex.

The EM roadmap can help establish a more direct coupling of national laboratory capabilities and infrastructure with EM's high-priority long- and medium-term R&D needs. The committee's final report will assess the national laboratories' capabilities and infrastructure that will be needed to address EM's long-term, high-risk cleanup challenges, and how their support might be leveraged with other programs at the laboratories.

[8] See http://srnl.doe.gov/newsroom/2006news/em-corp-lab.pdf.

Needs and Opportunities for EM Research and Development

As stated at the beginning of this report, the committee generally agrees with the five program areas[9] listed in the draft EM roadmap. This section describes some of the higher-priority, medium- to long-term needs in the draft roadmap's program areas, and is based on the science and technology needs for EM cleanup discussed at the March 2007 workshop (NRC, 2007) and during the committee's three site visits.

Tank waste cleanup: A very expensive and long-term problem for the EM cleanup program involves retrieval of waste from the tanks at the Savannah River Site (SRS) and Hanford, processing the waste to separate the radionuclides into a high-level waste stream and a low-activity waste stream (intended to contain mostly non-radioactive chemicals), and converting these streams to monolithic solid waste forms destined for deep-underground or near-surface disposal, respectively. Tank waste retrieval and tank cleanup present challenges that are likely to be different for each tank. While some steps in the cleanup process can be used repeatedly in several tanks, the nature of the wastes, the configuration of the tanks, and a host of other factors dictate the process for cleanup of each tank. For example, the Hanford Office of River Protection presented a list of technology needs for its tank cleanup, and estimated that $109 million of R&D funding would be necessary to address these needs during the next 5 years (Mauss, 2007). A previous NRC (2006) committee examined challenges of tank waste cleanup at Hanford, INL, and SRS. Its final report described additional R&D needed to improve waste retrieval, waste processing, and tank closure.

Tank waste immobilization: Borosilicate glass was selected in the late 1970s as the baseline waste form for immobilizing tank sludge, primarily because of its long-term durability and its ability to incorporate a wide variety of waste constituents. However, use of borosilicate glass to immobilize DOE tank waste requires considerable pretreatment to remove bulky (e.g., sodium salts) and low-solubility (e.g., chromium) chemicals to increase the amount of waste that can be incorporated per volume of glass (waste loading).

EM has an important opportunity to develop alternatives to the borosilicate glass baseline for waste processing. Other waste forms may allow higher waste loadings and/or be fabricated more economically and faster, while meeting the anticipated requirements for disposal. Iron-phosphate-based glasses and metal matrixes were described to the committee as possible alternatives that may provide much higher loadings and better durability than borosilicate glass. The committee was also briefed on an induction heating method that might produce borosilicate or other glasses more efficiently and offer potentially significant advantages over Joule heating,

[9] The initial draft of the EM roadmap (DOE 2007b) included only the first three areas listed in Sidebar 1. Mark Gilbertson added the last two in a revision of the roadmap that he described to the committee at its Richland, Wash., meeting on November 2, 2007. The committee did not discuss needs and opportunities in these last two areas before drafting this interim report.

which is the current baseline (Roach and Gombert, 2007). Such alternatives could provide large cost savings, since the cost of operating the processing and solidification facilities, such as those planned for Hanford, is at least $500 million annually (Mauss, 2007).

Groundwater and soil remediation: Subsurface contamination at the major sites includes inorganic materials such as uranium, technetium, and mercury as well as organic materials such as chlorinated solvents. Remediation requires characterization of subsurface contamination, understanding the soil structure and hydrologic conditions that will affect the mobility of the contaminants in the subsurface over long periods of time, technical options for remediation and/or containment of the contaminants, and an understanding of the longevity of containment options. Some important groundwater and soil remediation challenges remain unresolved at EM sites.

One ongoing challenge is the detection, removal, and/or containment of dense non-aqueous phase liquids (DNAPLs) such as carbon tetrachloride. Carbon tetrachloride occurs from near-surface to deep in the difficult-to-characterize fluvial gravels underlying the Hanford site, and it also occurs in fractured bedrock aquifers, including one of the fractured aquifers beneath the Oak Ridge Reservation. The complexity of remediating DNAPL contamination at the Oak Ridge Reservation's East Tennessee Technology Park is driving a request for a "technical impracticability" waiver from the State of Tennessee. Even if contaminant removal is precluded because cleanup is deemed technically impractical, science-based detection, monitoring, and decision-making protocols are needed to support arguments for such a technical impracticability waiver and ongoing risk management at the site. Basic understanding of how contaminant plumes may be attenuated by sorption, diffusion into low-permeability zones, biodegradation, and other processes can help EM determine the best approaches to deal with such contaminants.

Groundwater contaminants such as DNAPLs are also common problems at industrial sites. Although the committee has not specifically addressed its task item on leveraging, groundwater remediation is a likely opportunity for EM to leverage its work with private-sector organizations. Clearly EM is not working in isolation, and the leveraging would be expected to go both directions (i.e., industry can enlighten DOE and DOE can enlighten industry). Leveraging R&D with the Environmental Protection Agency, the federal regulator for hazardous chemical remediation, to strengthen the scientific basis for cleanup requirements would also benefit EM. The committee will discuss opportunities for leveraging in its final report.

Both Hanford and INL face complex challenges with the use of existing investigative approaches and technologies to monitor contaminant migration in the deep vadose zone. At Hanford there is also a need to develop effective and less costly remedial techniques for characterizing and managing or removing carbon tetrachloride and technetium-99 that are located in heterogeneous, partially or fully saturated sediments many tens of meters below the ground surface.

Long-term performance of caps and barriers: EM is responsible for leaving sites in a condition suitable for long-term stewardship and is relying heavily on caps and barriers to contain buried wastes and contaminant plumes at many sites. Sustained R&D investments are needed to develop effective monitoring strategies for containment options. Ideally, such monitoring strategies would include sensor networks (external to and/or within barriers) that could provide real-time, long-term information (e.g., radiation levels, moisture, pH, temperature profiles) that is important to the cap and barrier performance. This information is needed sooner, rather than later, so that a realistic performance estimate at different sites, and under different conditions, can be constructed, and hence better predictive models can be developed to provide advanced warning of possible barrier failures as well as a knowledge base for further improvements in design and construction.

Facility deactivation and decommissioning (D&D): Transite panels were used as siding on many production-era DOE buildings. Removal of transite panels is an acute problem for decommissioning the gaseous diffusion plants at Oak Ridge (McCracken, 2007) and probably at other sites. Because production-era transite contains asbestos, worker health and safety regulations require careful handling to prevent breaking of pieces from the main panel, even though this siding is robust, non-powdery, and non-flaking. As a result of these regulations, workers have to manually handle the heavy transite panels often high off the ground and in a limited space (e.g., in a basket lift). According to Oak Ridge, the health and safety regulations applied generically to asbestos may actually increase the hazards to the workers who must remove these panels.[10] Improved science- and technology-based approaches might include the development of robotic devices to remove asbestos-bearing materials or a comprehensive risk assessment to provide a scientific basis for reviewing the relevant regulations.

Current plans for cleanup and closure of DOE sites often call for mid- to long-term stabilization of facilities awaiting future D&D or slated for long-term stewardship. Weathering and subsequent destabilization of these structures could result in release of contaminants to the environment. Retaining relevant expertise and supporting research programs to develop stabilization methodologies and technologies to limit the effects of building deterioration, while not hindering or complicating the building's future disposition, are important medium- to long-term challenges for EM. Maintaining aging buildings until they eventually undergo D&D will also require monitoring and sensing technologies, some of which could be leveraged from groundwater protection and remediation programs mentioned previously.

Conclusions

This interim report provides the committee's initial observations in its study to provide technical and strategic advice to assist DOE's development and implementation of the EM

---

[10] Oak Ridge Technology Summary Sheets: Improved Method for Transite Removal. Handout to the committee during its visit to the Oak Ridge Reservation, June 14, 2007.

Cleanup Technology Roadmap. In concluding this interim report, the committee wishes to highlight the following:

- The committee generally agrees with the five program areas for strategic R&D presented in EM's draft Cleanup Technology Roadmap.
- According to the range of technology needs presented to the committee and the committee's initial observations, the committee judges that existing knowledge and technologies are inadequate for EM to meet all of its cleanup responsibilities in a safe, timely, and cost-effective way. Meeting current and future EM challenges will require the results of a significant, ongoing R&D program.
- The committee is concerned that the medium- and long-term research component of EM's program has largely disappeared. Implementing the roadmap will require substantial and continuing federal support for medium- and long-term R&D for technologies focused on high-priority cleanup problems.

The committee views the Cleanup Technology Roadmap as a continuing effort to establish an effective longer-term R&D program in support of EM's cleanup activities. The need for such a program has not diminished in the 11 years since the NRC (1997) report Building an Effective Environmental Management Science Program. Unless EM can provide substantial and continuing support for medium- and long-term R&D, its efforts to bridge current technology gaps, maintain needed capabilities and infrastructures at national laboratories, and initiate leveraging of other research programs are not likely to be effective.

Our final report, which will fully address the statement of task, will be completed in early 2009 in accord with the schedule we discussed with you during the committee's Richland, Wash. meeting.

Sincerely,

Edwin Przybylowicz, Chair

Allen Croff, Vice Chair

Attachment A: Statement of Task
Attachment B: Committee Roster
Attachment C: References

ATTACHMENT A
STATEMENT OF TASK

A National Academies committee will provide technical and strategic advice to the DOE-EM's Office of Engineering and Technology to support the development and implementation of its cleanup technology roadmap. Specifically, the study will identify:

- Principal science and technology gaps and their priorities for the cleanup program based on previous National Academies reports, updated and extended to reflect current site conditions and EM priorities and input from key external groups, such as the Nuclear Regulatory Commission, Defense Nuclear Facilities Safety Board, Environmental Protection Agency, and state regulatory agencies.
- Strategic opportunities to leverage research and development from other DOE programs (e.g., in the Office of Science, Office of Civilian Radioactive Waste Management, and the National Nuclear Security Administration), other federal agencies (e.g., Department of Defense, Environmental Protection Agency), universities, and the private sector.
- Core capabilities at the national laboratories that will be needed to address EM's long-term, high-risk cleanup challenges, especially at the four laboratories located at the large DOE sites (Idaho National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, and Savannah River National Laboratory).
- The infrastructure at these national laboratories and at EM sites that should be maintained to support research, development, and bench and pilot scale demonstrations of technologies for the EM cleanup program, especially in radiochemistry.

The committee will provide findings and recommendations, as appropriate, to EM on maintenance of core capabilities and infrastructure at national laboratories and EM sites to address its long-term, high-risk cleanup challenges.

ATTACHMENT B
COMMITTEE ROSTER

COMMITTEE ON DEVELOPMENT AND IMPLEMENTATION OF A CLEANUP TECHNOLOGY ROADMAP

EDWIN P. PRZYBYLOWICZ, chair, Eastman Kodak Company (retired), Webster, New York
ALLEN G. CROFF, vice-chair, Oak Ridge National Lab (retired), St Augustine, Florida
RICHELLE M. ALLEN-KING, University of Buffalo, New York
SUE B. CLARK, Washington State University, Pullman
PATRICIA J. CULLIGAN, Columbia University, New York City, New York
RACHEL J. DETWILER, Braun Intertec Corporation, Minneapolis, Minnesota
THOMAS F. GESELL, Idaho State University, Pocatello
GARY HALADA, State University of New York, Stony Brook
CAROLYN L. HUNTOON, CLH Associates, Inc., Barrington, Rhode Island
EDWARD LAHODA, Westinghouse Science and Technology Center, Pittsburgh, Pennsylvania
ROBIN ROGERS, University of Alabama, Tuscaloosa; The Queen's University of Belfast, Northern Ireland, UK
GARY S. SAYLER, University of Tennessee, Knoxville
ANDREW M. SESSLER, Lawrence Berkeley National Laboratory (retired), Berkeley, California
J. LESLIE SMITH, University of British Columbia, Vancouver, Canada

Staff
JOHN R. WILEY, Senior Program Officer
MANDI M. BOYKIN, Senior Program Assistant

ATTACHMENT C
REFERENCES

DOE (U.S. Department of Energy). 2007a. Vision 2020: The Lighting Technology Roadmap. Washington, D.C.: DOE Office of Building Technology, State and Community Programs, Energy Efficiency and Renewable Energy. http://www.eere.energy.gov/buildings/info/documents/pdfs/lighting_roadmap_compressed.pdf.

DOE. 2007b. Engineering and Technology Roadmap: Reducing the Uncertainty in the EM Program. Washington, D.C.: DOE Office of Environmental Management. April. (Draft).

Mauss, B. 2007. Hanford HLW Program: Challenges to Cleanup. Presentation to the Committee on Development and Implementation of a Cleanup Technology Roadmap. Richland, Wash.: U.S. Department of Energy Office of River Protection, October 31.

McCracken, S. 2007. EM Science and Technology Challenges at the Oak Ridge Reservation. Presentation to the Committee on Development and Implementation of a Cleanup Technology Roadmap. Oak Ridge, Tenn.: Oak Ridge National Laboratory Operations Office, June 13.

Michaels, G. 2007. ORNL Nuclear Hot Cell Facilities. Presentation to the Committee on Development and Implementation of a Cleanup Technology Roadmap. Oak Ridge, Tenn.: Oak Ridge National Laboratory, June 13.

NRC (National Research Council). 1997. Building an Effective Environmental Management Science Program: Final Assessment. Washington, D.C.: National Academy Press. http://books.nap.edu/catalog.php?record_id=5557.

NRC. 2000. Alternatives for High-Level Waste Salt-Processing at the Savannah River Site. Washington, D.C.: National Academy Press. http://books.nap.edu/catalog.php?record_id=9959.

NRC. 2001. A Strategic Vision for Department of Energy Environmental Quality Research and Development. Washington, D.C.: National Academy Press. http://books.nap.edu/catalog.php?record_id=10207.

NRC. 2003. Improving the Scientific Basis for Managing DOE's Excess Nuclear Materials and Spent Nuclear Fuel. Washington, D.C.: National Academies Press. http://www.nap.edu/catalog.php?record_id=10684.

NRC. 2005. Improving the Characterization and Treatment of Radioactive Wastes for the Department of Energy's Accelerated Site Cleanup Program Washington, D.C.: National Academies Press. http://books.nap.edu/catalog.php?record_id=11200.

NRC. 2006. Tank Waste Retrieval, Processing, and On-Site Disposal at Three Department of Energy Sites. Washington, D.C.: National Academies Press. http://www.nap.edu/catalog.php?record_id=11618.

NRC. 2007. Science and Technology Needs for DOE Site Cleanup: Workshop Summary. Washington, D.C.: National Academies Press. http://www.nap.edu/catalog.php?record_id=11932.

Roach, J. and D. Gombert. 2007. Presentation to the Committee on Development and Implementation of a Cleanup Technology Roadmap. Idaho Falls, Idaho: Idaho National Laboratory, August 29.

Stewart, T. 2007. Challenges to Cleanup: Soils and Groundwater Contamination. Presentation to the Committee on Development and Implementation of a Cleanup Technology Roadmap. Richland, Wash. Pacific Northwest National Laboratory, October 31.

Walton, T. 2007. PNNL 2007 EM Business Summary. Provided to the Committee on Development and Implementation of a Cleanup Technology Roadmap. Richland, Wash. Pacific Northwest National Laboratory, October 31.